

ATLAS TRANSMISSION LINE/TRANSITION DESIGN AND FABRICATION STATUS*

E. O. Ballard, D. M. Baca, H. A. Davis, J. M. Elizondo, **
R. F. Gribble, K. E. Nielsen, G. V. Parker, R. L. Ricketts, G. Valdez
Los Alamos National Laboratory
Los Alamos, New Mexico 87545 USA

Abstract

Atlas is a pulsed-power facility under development at Los Alamos National Laboratory to drive high-energy density experiments. Design has been completed for this new generation pulsed-power machine consisting of an azimuthal array of 24, 240-kV Marx modules and transmission lines supplying current to the load region at the machine center.

The transmission line consists of a cable header, load protection switch, and tri-plate assembly interfacing to the center transition section. The cable header interface to the Marx module provides a mechanism to remove the Marx module for maintenance without removing other components of the transmission line. The load protection switch provides a mechanism for protecting the load during charging of the Marx in the event of a pre-fire condition. The aluminum tri-plate is a low-inductance transmission line that carries radial current flow from the Marx energy storage system at the machine periphery toward the load. All transmission line components are oil insulated except the solid-dielectric insulated power flow channel connected directly to the load.

The transition region at the machine center consists of several components that enable the radial converging vertical transmission lines to interface to a horizontal disk/conical power flow channel delivering current to the load. The current carrying transition components include the high-voltage and ground conductors interfacing to the tri-plate transmission lines. The tri-plate tank attachment ring interfaces to the tri-plate tanks and the base-plate. The base-plate supports the transition components and interfaces to the center support structure of the machine. The bottom insulator also attaches to the base-plate and to the high-voltage conductor, providing an oil containment seal between the transition and vacuum vessel.

Design has been completed for all Atlas components. Some prototype hardware fabrication has been completed and first article hardware is in various stages of completion. The first article is a single line of the machine and includes a Marx module, cable header, load protection switch, tri-plate transmission line, and a dump load for testing.

Testing is in progress on some prototype and first article components to verify performance before production begins on critical system components.

Production will soon begin for much of the overall system, including the Marx tanks, tri-plate tanks, support structure, some transition components, and the personnel platform. These components will be fabricated and

installed while the remaining internal components are being fabricated.

I. MACHINE CONFIGURATION

The Atlas machine configuration is shown in Figure 1. The 23 MJ capacitor bank is housed in 12 separate Marx tanks surrounding the target chamber. Each tank contains two, independently removable maintenance units composed of a set of four Marx modules. The Marx modules have four capacitors charged at up to ± 60 kV and two rail-gap switches. When the switches are triggered, the Marx modules erect at up to 240 kV. The output of each maintenance unit is connected to a mechanically fast-acting load protection switch (LPS) that prevents the load from being damaged in case of a pre-fire. A set of 24, tapered, vertically oriented, oil insulated, tri-plate transmission lines transmit the current to a transition section at a radius of 48.85-in. (1.24 m). This couples the current to a solid-dielectric insulated radial and conical transmission line that delivers current to the load. The load is housed in a 72-in. (1.83 m) diameter, stainless steel, vacuum chamber that also provides debris containment with an internal debris shield that protects the vacuum vessel wall.

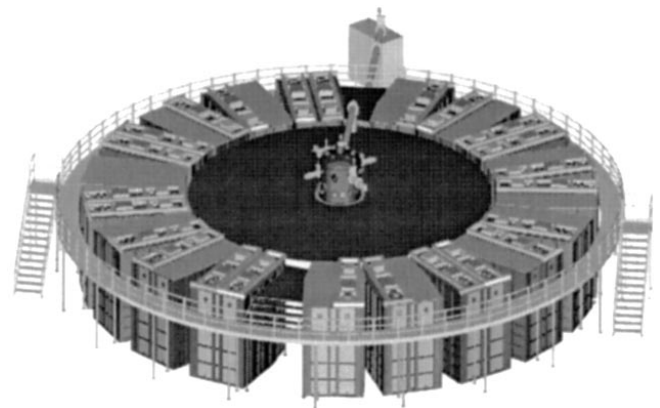


Figure 1. Atlas Machine Configuration

II. ATLAS MACHINE OPERATION

The output of each Marx maintenance unit is connected to a low inductance, oil-insulated, cable header (CH) by 56, 50 Ohm cables. The CH provides a means to quickly

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE JUN 1999		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE Atlas Transmission Line/Transition Design And Fabrication Status				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Los Alamos National Laboratory Los Alamos, New Mexico 87545 USA				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES See also ADM002371. 2013 IEEE Pulsed Power Conference, Digest of Technical Papers 1976-2013, and Abstracts of the 2013 IEEE International Conference on Plasma Science. Held in San Francisco, CA on 16-21 June 2013. U.S. Government or Federal Purpose Rights License.					
14. ABSTRACT Atlas is a pulsed-power facility under development at Los Alamos National Laboratory to drive high-energy density experiments. Design has been completed for this new generation pulsed-power machine consisting of an azimuthal array of 24, 240-kV Marx modules and transmission lines supplying current to the load region at the machine center. The transmission line consists of a cable header, load protection switch, and tri-plate assembly interfacing to the center transition section. The cable header interface to the Marx module provides a mechanism to remove the Marx module for maintenance without removing other components of the transmission line. The load protection switch provides a mechanism for protecting the load during charging of the Marx in the event of a pre-fire condition. The aluminum tri-plate is a low-inductance transmission line that carries radial current flow from the Marx energy storage system at the machine periphery toward the load. All transmission line components are oil insulated except the solid-dielectric insulated power flow channel connected directly to the load.					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 4	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

disconnect the maintenance unit from the rest of the system for servicing. Each CH is connected by a second set of 56, 50 Ohm cables to the input of the load protection switch. The LPS shorts each maintenance unit through a low inductance path to ground during capacitor charging. In case of a pre-fire, only approximately 35 kA flows through the load and permanent damage to the load does not occur, thus preventing costly load replacement. Once the capacitors are charged, the LPS opens the path through the short in 0.25 ms for firing into the load. This reduces the time the load is vulnerable to a pre-fire from several seconds to a fraction of a second, which is sufficient to meet the 95% shot reliability requirement.

As seen in Figure 2, the output of each LPS is connected to an oil insulated, tri-plate transmission line. The inter-electrode gap is nominally 0.811-in. (2.06 cm) and the lines taper from a height of 68-in.(1.75 m) at the switch end to 12.5-in.(0.32 m) at the output end. The tri-plate aluminum conductors are held together by 20 nylon insulating spacers which maintain the gap between the conductors. The tri-plate assemblies are inserted as a unit into radial, oil-filled, steel tanks. The negative, high-voltage, center conductor is 1-in. (2.54 cm) thick and the outer ground conductors are 0.625-in. (1.59 cm) thick.

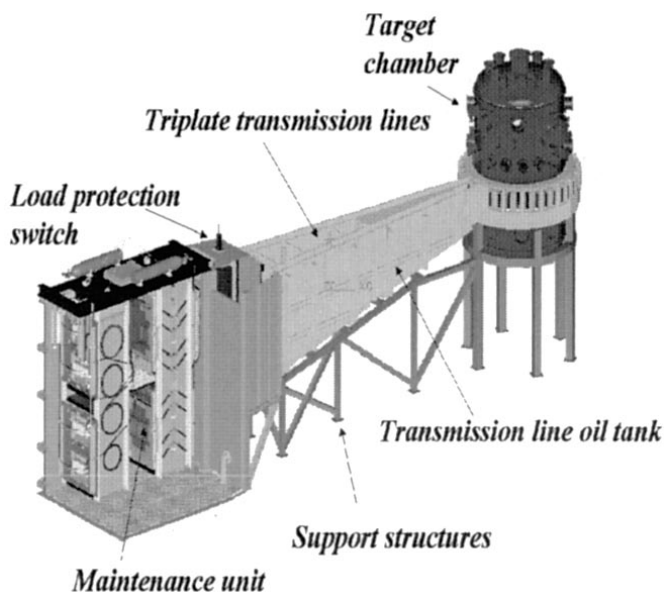


Figure 2. Transmission Line Configuration

The 24, tri-plate transmission lines connect to a transition section at a radius of 48.85-in. (1.24 m). The transition couples the transmission lines to a disk/conical solid dielectric insulated power flow channel (PFC) that interfaces to the load. The center high-voltage conductor transmits shock loads from the current pulse to the support structure and provides seals for vacuum and insulating oil. The high-voltage conductor sits on insulating disk segments, which isolate this component from the base-plate and allows the base-plate and vacuum chamber to be grounded. An exploded view of the transition section and PFC is shown in Figure 3.

The center high-voltage conductor of the tri-plate line connects to the radial vanes of the high-voltage transition conductor through a current joint. The outer ground conductors of the tri-plate are also connected to the ground transition conductor through a similar current joint, which allows the tri-plate to be engaged or disengaged from the transition. Current flows from the vertical surfaces of the transition to the central hub of the high-voltage and ground transition conductors.

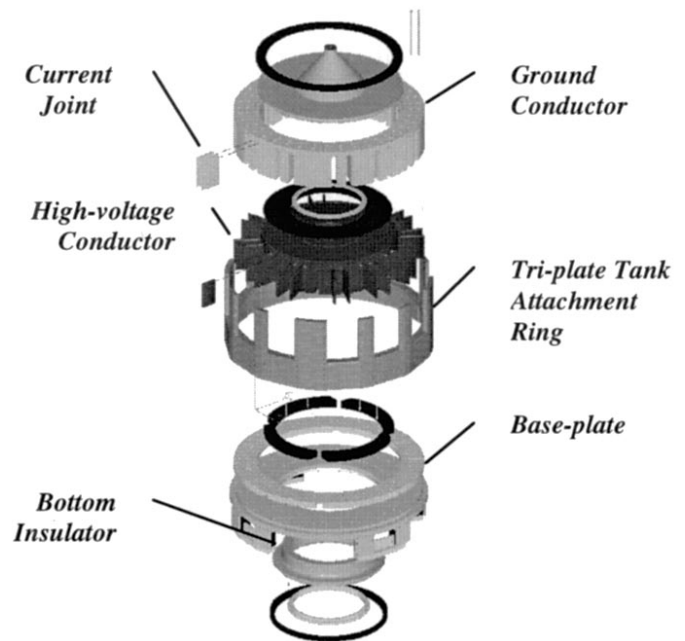


Figure 3. Transition Section Exploded View

The power flow channel high-voltage and ground conductors attach to the corresponding transition conductors to continue the current path to the load. The PFC operates with severe radial forces on the conductors increasing inversely as the square of radius. This results in significant damage to this hardware in the region near the load during a shot. The PFC is replaced for each shot, since it cannot be effectively re-conditioned. As presently envisioned, the PFC will be insulated with solid-dielectric to minimize the relatively large inductance in this region. The conductor configuration consists of a disk-line transitioning to a conical section, which connects to the load. The conical section elevates the load above the experimental platform for diagnostic access. The PFC assembly will be held in place during a shot by steel weights contacting the upper conductor of the PFC to allow the assembly to stay intact sufficiently long for the shot to occur.

III. ATLAS SUBSYSTEM CONFIGURATION

A. Transmission Line Components

The Atlas transmission line consists of a cable header, which provides the mechanism to disconnect the Marx

maintenance unit from the transmission line and allows the Marx to be removed for maintenance without disruption to the remainder of the transmission line. Half of the cable header remains in place with the 56 cables connecting it to the load protection switch. The load protection switch attaches directly to the tri-plate with a bolted current joint that has a nominal current density of approximately 5 kA/cm. The cable header and load protection switch are suspended from a lid that rests on the top surface of the Marx tank. Figure 4 shows the lid/CH/LPS assembly.

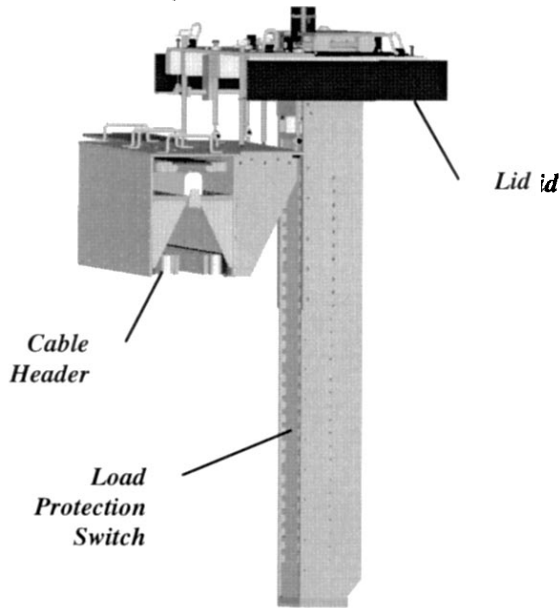


Figure 4. Cable Header/Load Protection Switch Assembly

The tri-plate transmission line delivers current to the machine center transition section through the current joint that interfaces the tri-plate to the transition. Figure 5 shows the tri-plate with the 20 stand-off insulators used to establish the proper plate separation and support of the center high-voltage conductor. The tri-plate is approx. 20 feet (6 m) long with a tri-angular shape that is necessary to reduce the width to make the interface with the transition section.

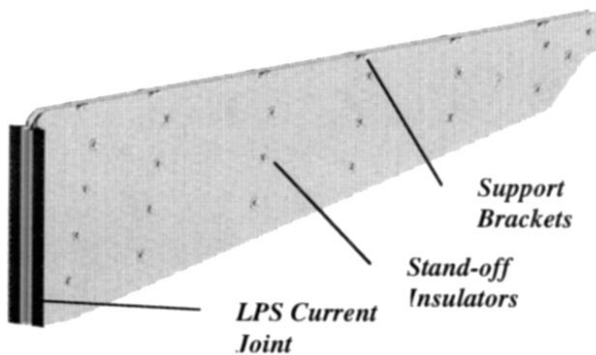


Figure 5. Tri-plate Assembly

A current joint interfaces the tri-plate to the transition and provides the capability to disconnect the tri-plate from the transition, if necessary, without disturbing the transition assembly. The current joint uses a high-pressure interface obtained using an eccentric rod that presses the interface together when turned into position at assembly. Top and bottom clamp bars, with copper wire interfaces, also provide additional current transfer capability to prevent burning in high current density regions. Figures 6 shows the current joint assembly as it would interface between the tri-plate and transition.

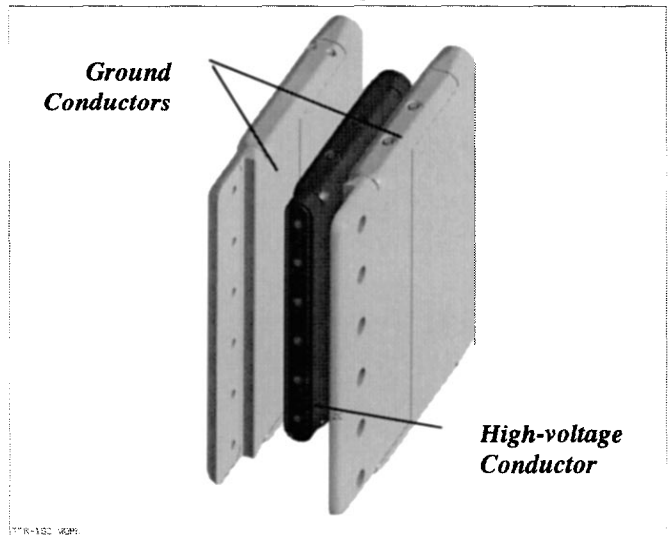


Figure 6. Current Joint Assembly

Figure 7 is an exploded view of the center conductor showing how the current joint slides together and is locked with an eccentric rod to apply pressure to the contact surfaces.

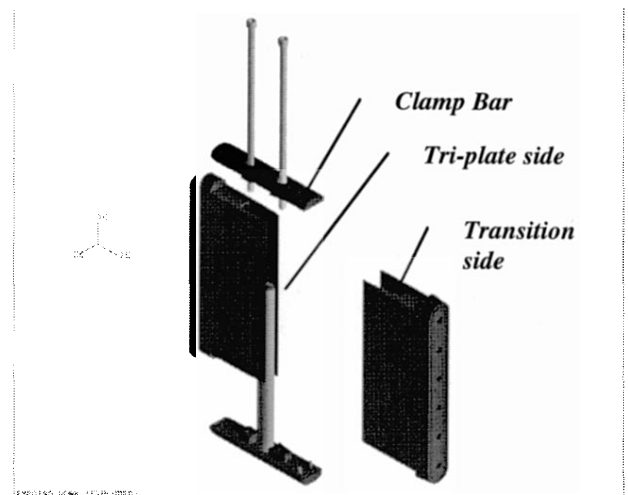


Figure 7. High-voltage Current Joint Exploded View

B. Transition Components

The Atlas transition is a compact assembly at the machine center, as indicated previously by Figure 3. Two structural components provide the interface to the oil

tanks containing the tri-plates and the center support structure. These are the tri-plate tank attachment ring and the base-plate. The tri-plate tank attachment ring is a large, machined, stainless steel casting that provides the center structural hub of the machine. The base-plate interfaces to this ring, the center structure, and the bottom insulator.

The two current carrying components of the transition are the high-voltage and ground conductors shown in Figures 8 and 9, respectively. These components fit together with 0.689-in. (1.75 cm) of oil insulation between the fins of the high-voltage conductor and the arced cut-outs of the ground conductor. The voltage has decreased in this region to 140 kV, but the current density is increasing as it concentrates on the top surface of the fins and arc regions of the conductors.

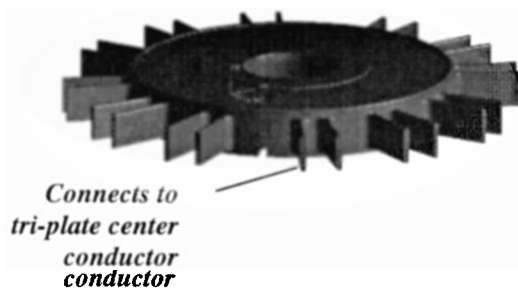


Figure 8. Transition high-voltage Conductor

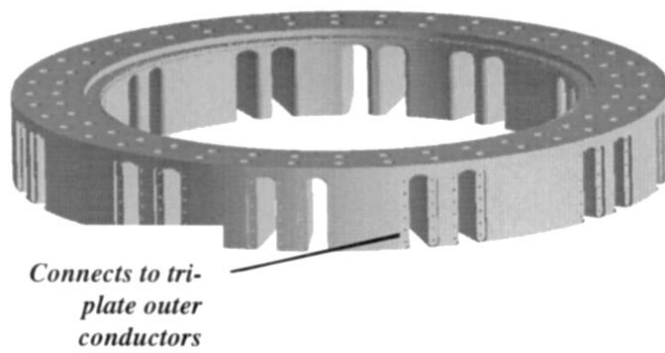


Figure 9. Transition Ground Conductor

A current joint with high current density exists at the interface between the transition conductors and the power flow channel component. The PFC is detached and replaced at this interface after each shot. Also, another PFC concept is being developed that would allow this interface to remain in-place for several shots with the damaged part replaced at a different interface closer to the machine center.

The other main component of the transition is the bottom insulator, which provides the oil-to-vacuum interface inside the vacuum vessel. This insulator also

electrically insulates the high-voltage transition conductor from the grounded base-plate and vacuum chamber. This component is made from cast polyurethane and machined to the final configuration shown by Figure 10. This component can be removed and replaced, if damaged, without disturbing the transition assembly. A handling fixture used for installing the bottom spool and head of the vacuum vessel can also be used for installation and removal of this insulator.

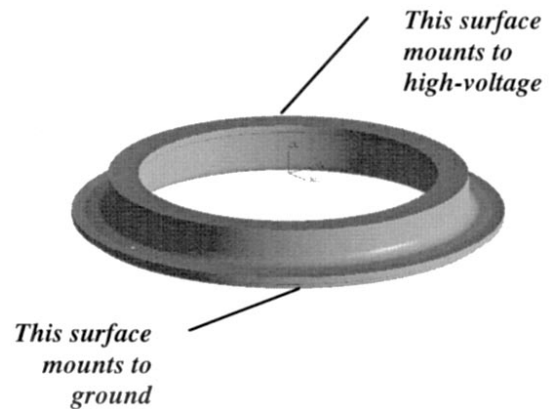


Figure 10. Bottom Insulator

IV. FABRICATION AND TESTING

A prototype cable header, load protection switch, tri-plate tank and half-length tri-plate have been fabricated and installed for high voltage testing of these components. Test results indicate that the present design for these components meets high-voltage breakdown requirements as established for machine operation.

Fabrication of the first article transmission line assembly, which consists of the Marx module, cable header, load protection switch, and full-length tri-plate, is nearly complete. Full current testing of this complete transmission line and Marx will begin in the near future to validate the overall transmission line design.

The production Request-for-Proposal for the machine support structure, Marx tanks, tri-plate tanks, transition structural components, personnel platform and catwalk is presently being evaluated and an award for fabrication and installation of these components will soon be made.

* Work sponsored by Los Alamos National Laboratory, under US DOE contract W-7405-ENG-36.

** Allied Signal FM&T/NM